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PI Controller for PWM Converter using Genetic Algorithms

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***Abstract**: This paper has two main goals: to determine appropriate parameter values for the voltage PI controller and to develop a novel control system along with reactance parameter design for PWM converters. A description regarding the application of genetic algorithms to optimize PWM converter controller parameters exists in the presented paper. The study depicts how the stability region acts at various sample times. MATLAB serves to develop a dc-link PWM ac/dc converter simulation model and genetic algorithms perform an off-line search mechanism. The simulation data reveals proper converter operation under PMDC motor loads alongside an effective and genuine performance of the proposed control method.*

***Keywords**: Genetic Algorithms PI voltage controller PWM rectifier THD*

I. Introduction

The analysis and controller design of PWM converters becomes complex because both the driving load and device operation show non-linear characteristics. The PWM rectifier serves two purposes: allowing power transfer from ac link to dc link for power draw and blocking this transfer to accept power from dc link to ac source during power generation. A PWM rectifier functions as the main converter in front-end installation of a four-quadrant drive control system. The operational period of the dc link capacitor provides steady voltage levels without showing any ripples. The cyclic supply voltages determine how the three-phase input currents remain both sinusoidal and in phase configuration.

The PWM rectifier operates with unity power factor and controls the supply system harmonics. The connection between (i) three-phase AC supply and (ii) three-phase AC regenerative/back emfs of the PWM rectifier exists through the inductors of the source. The optimization setup of GA stands apart from most traditional optimization technologies. Design space serves as the necessary step to convert information into genetic space. The genetic algorithms require variable codes to operate. The key advantage of using variable space coding involves dividing the search area which remains continuous despite the function.

II. Proposed PWM Converter

Between two three-phase ac systems—that is, (i) a three-phase ac supply and (ii) the three-phase ac regenerative/back emfs of the PWM converter—the source inductors offer a power transfer link. The converter is controlled by an inner hysteresis current control loop and an exterior dc link voltage control loop. After being sensed, the dc link voltage is deducted from the reference voltage. The waves in the dc link voltage are eliminated by the dc link capacitor.

In order to reduce the ripples, a large value of the dc link capacitor is used. This is because larger ripples in the dc link current drawn by the drive inverter result in larger dc link voltage ripples. The suggested three-phase PWM boost converter with a high power factor. When the dc motor is in generating operating mode, the PWM converter allows power to flow from the dc link to the ac source and from the ac to the dc link during motoring operation. The dc link capacitor voltage is maintained steady and devoid of ripples while the drive is operating. The three-phase input currents are kept in phase with the supply voltages and sinusoidal. The converter guarantees unity power factor functioning and regulates the harmonics introduced into the supply system.

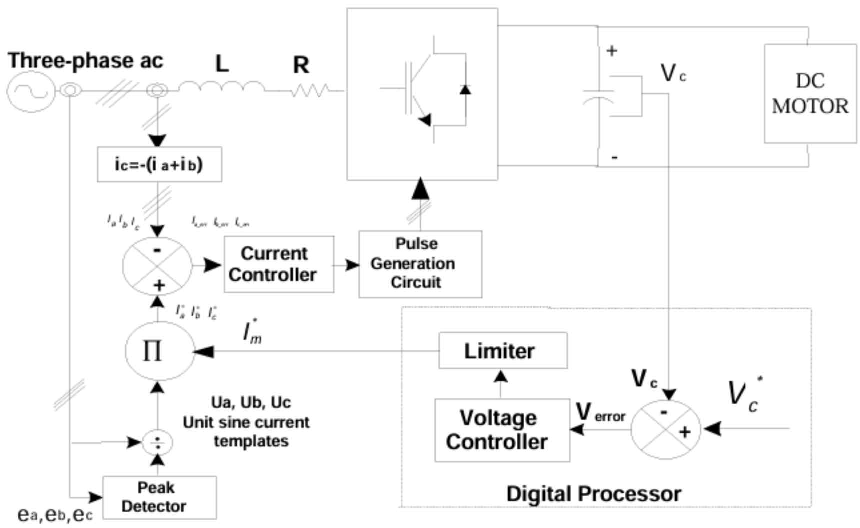

Fig 1: Control scheme of PWM converter

III. PI Gain Optimization Genetic Algorithm

Natural evolution forms the basis of investigation within GA. Evolution processes depend on chromosomes for their operation. The decoded structures and usage of the chromosome generate performance that natural selection monitors. Organisms tend to reproduce chromosomes that produce beneficial performance outcomes instead of those that create negative performance effects. A natural evolution process forms the basis of effective computer algorithms that solve difficult search problems[13]. GA functions to seek solutions for maximizing (or minimizing) problems using objective function statements.

The chosen crossover probability is 70%. Chromosome selection occurs randomly through the process which selects seven chromosomes out of twenty for the first group while selecting thirteen chromosomes from twenty for the second group. The third group maintains the chromosome collection that contains six chromosomes. The crossover site functions as a randomly selected integer that exists within a range from one to twenty-one chromosome bits. The portions of the chromosome that exist outside the crossover point get exchanged between the picked original chromosomes from Group 1 and Group 2.

The second chromosomes from both groups are retrieved for random crossover sites and container swapping occurs in their chromosome parts. The chromosomal processes are repeated identically for the seven chromosomes of each first and second group. A fresh population emerges from joining the 14 crossover group chromosomes with the additional 6 chromosomes of the third group. The chosen mutation probability is 0.5%. The new population receives random alteration to 0.5% of its string elements.

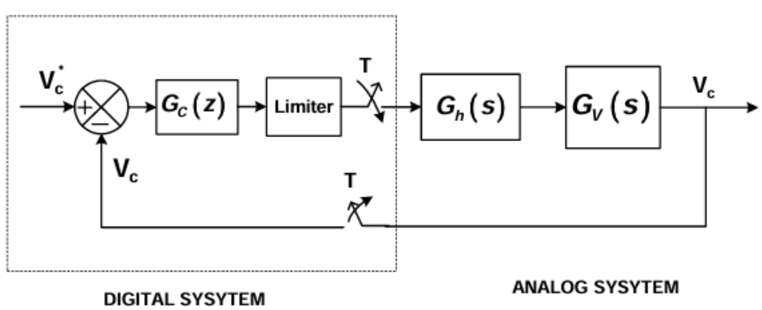

Fig 2: Closed loop control system of dc link voltage controller

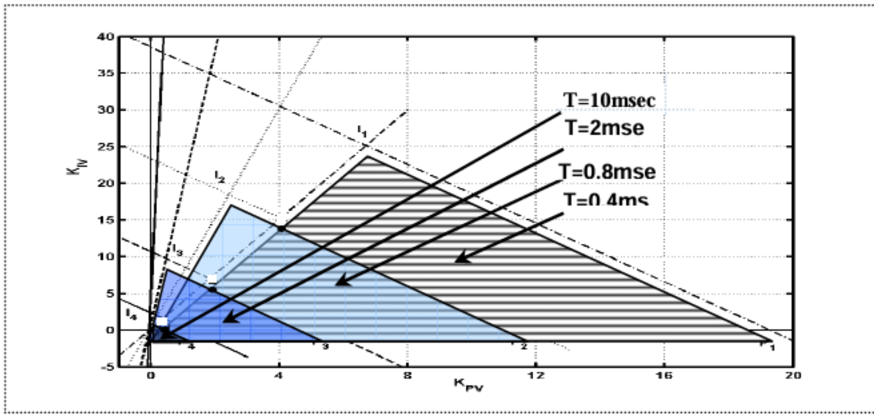

Fig 3: Variation in stability region with sampling period on K_{PV} and K_{IV} plane

IV. Result and Analysis

The best results emerge from methods other than trial and error. A space search method using genetic algorithms enables researchers to optimize the gains located in OP4CDO region of the K_{PV}-K_{IV} plane shown in figure 3. A starting point consists of 300 layers of chromosome [K_{PV} K_{IV}]. Figure 3 displays a shaded area that confines its highest value points and the minimum K_{PV} and K_{IV} values stand at 0.0001. ITAE becomes the chosen objective function for evaluation after observing the unit step response. The fitness function can be defined as Fitness = (1-0.5 penalty) (100/(1+ITAE)) due to its definition.

When the controller produces an overshoot exceeding 2 percent the penalty value switches to 1 whereas it remains unadjusted otherwise. Every new life cycle selects chromosomes with elevated scaled fitness ratings which stand a better chance of survival along with reproduction. The three breeding methods used to develop successive generations include reproduction followed by crossover and mutation. The population of chromosomes shown in Figure 4(b) was obtained after 200 generations while Figure 4(a) displays the initial 300-chromosome beginning population. Most chromosomes achieved enhanced fitness scores during the 200 generations of evolutionary process. The figures 4(b) depict chromosomes that exist between lower K_{IV} values and higher K_{PV} values. The 200th generation of chromosomes gets displayed with their fitness values and decoded K_{PV} along with K_{IV} values in figures 4(b) and (c). A chromosome with the maximum scaled fitness features K_{PV} set to 0.6021 along with K_{IV} set to 0.1056. Figure 5 illustrates the step response of controller gains with different K_{PV} values together with K_{IV} values which include K_{PV}=1.30 along with K_{IV}=0.14, K_{PV}=1.1 and K_{IV}=0.12, K_{PV}=0.6021 and K_{IV}=0.1056, and K_{PV}=0.3023 with KIV=0.0892. The optimal gain for the voltage controller includes K_{PV}=0.6021 along with K_{IV}=0.1056.

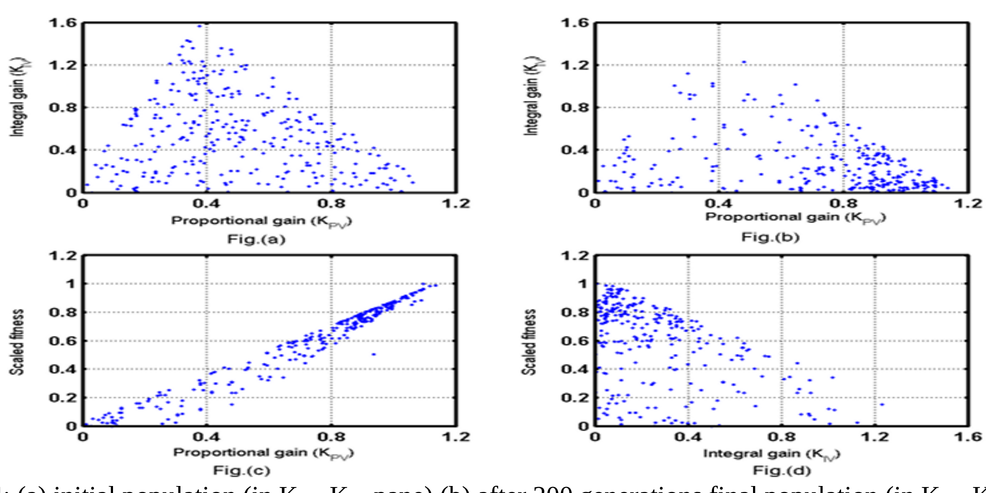

Fig 4: (a) initial population (in K_{PV}-K_{IV} pane) (b) after 200 generations final population (in K_{PV}-K_{IV} pane) (c) with respect to scaled fitness and K_{PV} and (d) with respect to scaled fitness and K_{IV}.

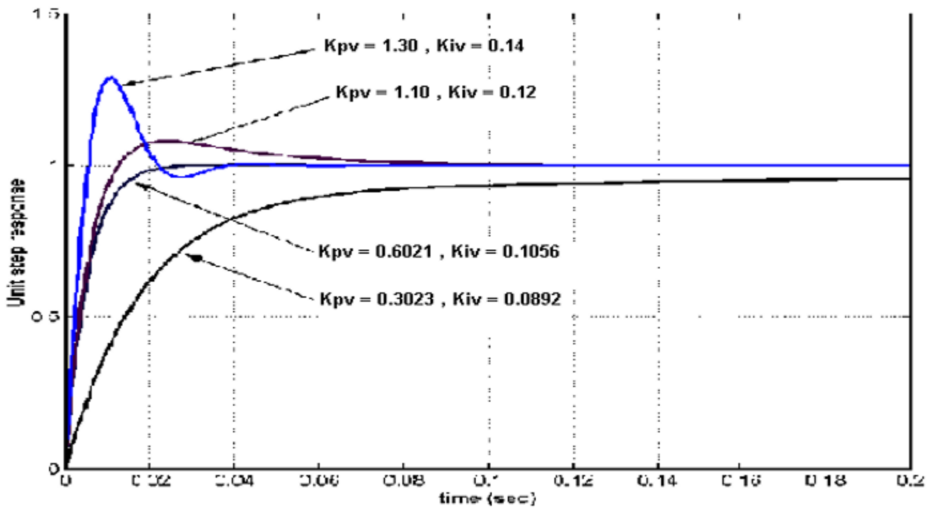

Fig 5: Unit step responses with different controller gains.

V. Conclusion

The converter model provides essential framework for creating the closed loop control system. A research was performed to identify the stability region for the voltage controller located on KP and KI planes. A calculation of unit step and unit impulse responses exists for the PWM converter's closed loop voltage controller. Ideal PI voltage controller gain values are identified through the application of genetic algorithms search approach. The PWM converter system achieves optimized system gains through its design to ensure required responsiveness.

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